Case Study and Energy Performance Optimization for Dell Children's Medical Center of Central Texas

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ABSTRACT
Dell Children's Medical Center of Central Texas (DCMCCT) is the first hospital in the world to achieve LEED Platinum certification. A major contributor to this certification is an on-site 4.3 Megawatt combined heating, cooling and power plant (CHP) owned and operated by Austin Energy that provides 100% of the hospital's electricity, chilled water and steam requirements. The operation and efficiency of this plant is not addressed by this paper.

The energy efficiency strategies employed for the design of the hospital included exhaust heat recovery, dedicated outside air units, BAS control strategies, lighting controls, and high performance glazing. Preconstruction energy modeling for the hospital was estimated at 17% better performance than an ASHRAE 90.1 compliant design.

Energy consumption for the first three months of operation was 75% over design estimates. Over the past eighteen months, the energy performance of the hospital has tracked within 5% of the modeled performance while the cooling degree days have been 25% greater than average.

BACKGROUND

From the inception of the master planning and programming for a replacement hospital for the ten year old Children's Hospital of Austin, two of the primary goals for the new hospital was for the capability of "grid independence" and for LEED certification. This vision evolved into a partnership between Austin Energy (AE) and the Seton Healthcare Network for AE to build an on site CHP to provide 100% of the hospital's utility requirements for a minimum 30 year period.

Austin Energy, which is a municipal utility provider owned by the City of Austin, is currently a national leader in providing wind energy to its service customers and began promoting energy conservation within its service boundaries in the early 1980s. AE is also one of the founding members of the USGBC, and was able to provide guidance and technical assistance throughout the project with the LEED certification efforts.

This venture was "out of the box" for Seton which is a financially conservative not-for-profit healthcare entity. However, Austin Energy had significant previous experience with district cooling and had recently completed a DOE CHP project. After some exploratory discussions, both entities ran numerous iterations of economic cost analyses in order to establish an agreeable utility rate structure. These efforts led to contract negotiations that took several months to complete.

THE HOSPITAL

DCMCCT consists of four levels of over 500,000 gross square feet of acute care children's hospital with 176 licensed beds. The patient rooms are segregated into 24 bed units including PICU, IMCU, Oncology, respiratory, surgical and general units and a 20,000 square foot 25 bed neonatal intensive care unit. Other significant areas of the hospital are as follows:

- The surgery department of the hospital is equipped with 9 ORs with associated PACU/PANDA area, 2 special procedure rooms and a shelled space for 3 additional ORs.
- A below ground 6,500 square foot Intraoperative OR suite addition was recently brought on line in July 2009.
- The Level 1 Trauma designated Emergency Department is approximately 35,000 square feet with 45 exam / treatment rooms, two Trauma rooms and CT Scan and radiology rooms.
- The Imaging department includes 2 Cath Labs, MRI and 15 imaging/radiology rooms.
- The 14,000 square foot laboratory operates 24/7,
- 6,000 sf Pharmacy,
- Full service dietary kitchen/dining area,
- Sleep lab,

- Inpatient and outpatient rehabilitation therapy department with a therapy pool
- 40,000 square foot administration area

Figure 1 illustrates the second floor area of the hospital.

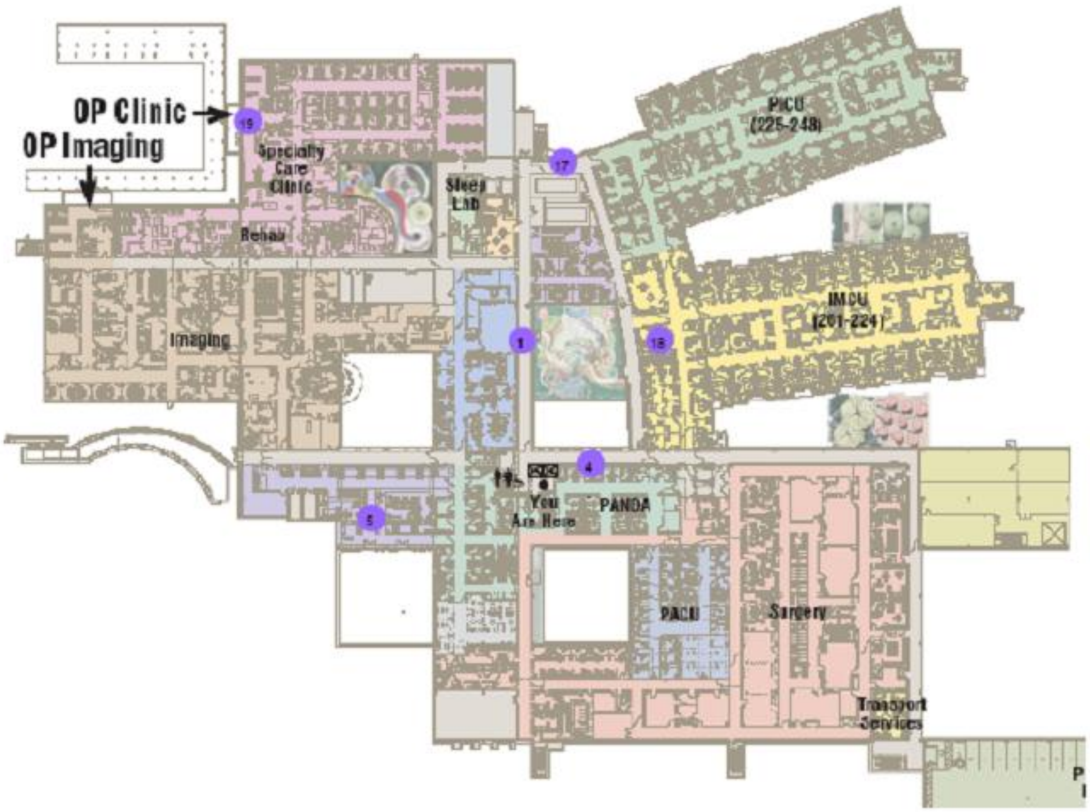

FIGURE 1 DCMCCT 2nd FLOOR PLAN

DESIGN

The architectural and MEP design for the hospital was developed as the discussions and negotiations with AE were ongoing. The schematic design included concepts with and without chillers, cooling towers, emergency generators and associated ancillary components. The construction manager for the project provided pre-construction estimating services and estimated a savings to Seton of approximately $6.5 million to not build a traditional central plant.

During this same period energy conservation measures were evaluated and those that met an 8 year simple payback period based on bin data analyses were selected for the design. These energy efficiency strategies included exhaust heat recovery, dedicated outside air units, high efficiency lighting, daylight harvesting controls, high performance glazing, building automation system monitoring and control strategies, and numerous other minor measures.

The HVAC design consisted of 21 distributed air handling units and six dedicated outside air units, all served by variable speed chilled water pumps. The variable speed air handling units were sized to serve departments and smoke zones to the maximum extent feasible, and the associated air distribution systems were designed with over 700 VAV air terminal units equipped with factory installed DDC control modules. Heating water steam heat exchangers produce heating water for

VAV and constant volume terminal unit reheat water coils.

AHU	Area Served	Bal SA cfm	OA cfm	% OA
1-1	Kitchen/Dining	31,350	8,240	26.3%
1-2	Maint/CSPD	38,685	9,400	24.3%
2-1	Surgical Svcs	48,000	10,000	20.8%
2-2	PACU/PANDA	26,200	8,700	33.2%
2-3	IMCU	19,950	6,685	33.5%
2-4	PICU	20,075	7,440	37.1%
2-5	Imaging Svcs	49,250	9,850	20.0%
2-6	Rehab/Spec Care	18,600	4,695	25.2%
3-1	Emg. Svcs	33,085	10,900	32.9%
3-2	Admitting/Admin	28,300	8,960	31.7%
3-3	Nursing Unit Spc Care	19,640	6,480	33.0%
3-4	Nursing Unit General Svcs	19,900	6,570	33.0%
3-5	Auditorium	3,500	1,000	28.6%
3-6	Admin	14,400	2,900	20.1%
4-1	Cardio	38,900	7,900	20.3%
4-2	Lab	16,000	11,000	68.8%
4-3	Surgical Nursing Unit	18,300	6,040	33.0%
4-4	Oncology Nursing Unit	25,100	8,285	33.0%
4-5	Lab Expansion	6,200	2,938	47.4%
Entry	Main Entry	22,100	4,420	20.0%
	Total	497,535	42,403	28.6%

TABLE 1 DCMCCT AIR HANDLING UNIT SUMMARY

The dedicated outside air units consist of steam preheat coils, clean steam humidifiers, chilled water coils and exhaust heat recovery as illustrated by Figure 2. Exhaust heat recovery system was incorporated into five of the six outside air units, and consists of a refrigerant heat pipe with a spray water assembly on the incoming building exhaust air side. General exhaust throughout the hospital is collected and ducted back to the OAUs. The OAUs provide pretreated (maximum 56 F dewpoint / minimum 42 F dewpoint) outside air to 20 of the 21 distributed air handling units serving the hospital.

The OAU serving the surgery suite, schematically shown by Figure 3, is a desiccant dehumidification unit designed to operate whenever the incoming OA dewpoint is above a 48F setpoint and to lower the dewpoint to 28.5F.

The total outside air provided to the hospital is approximately 0.3 cfm per square foot or 29% of the total supply air. The collected exhaust is approximately 45% of the outside air; however, exhaust from the more than 40 isolation rooms is not collected due to infection control concerns.

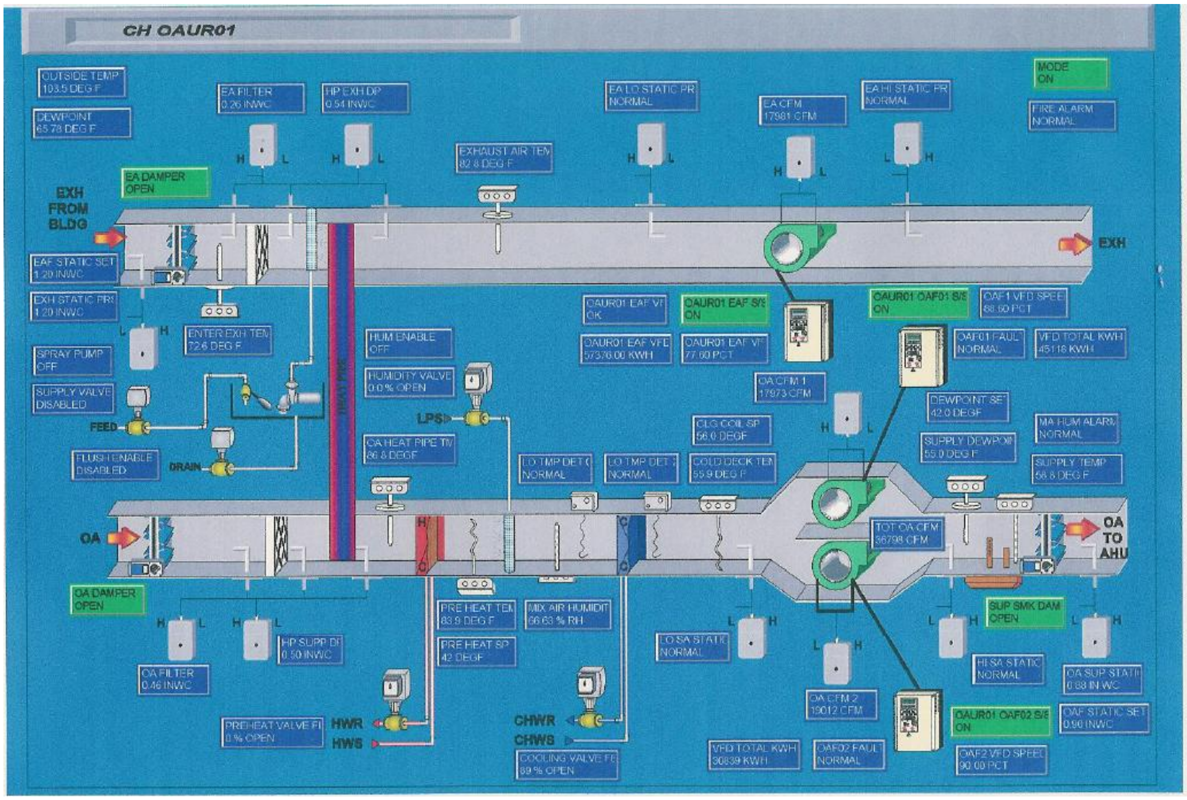

FIGURE 2 TYPICAL OUTSIDE AIR HANDLING UNIT SCHEMATIC

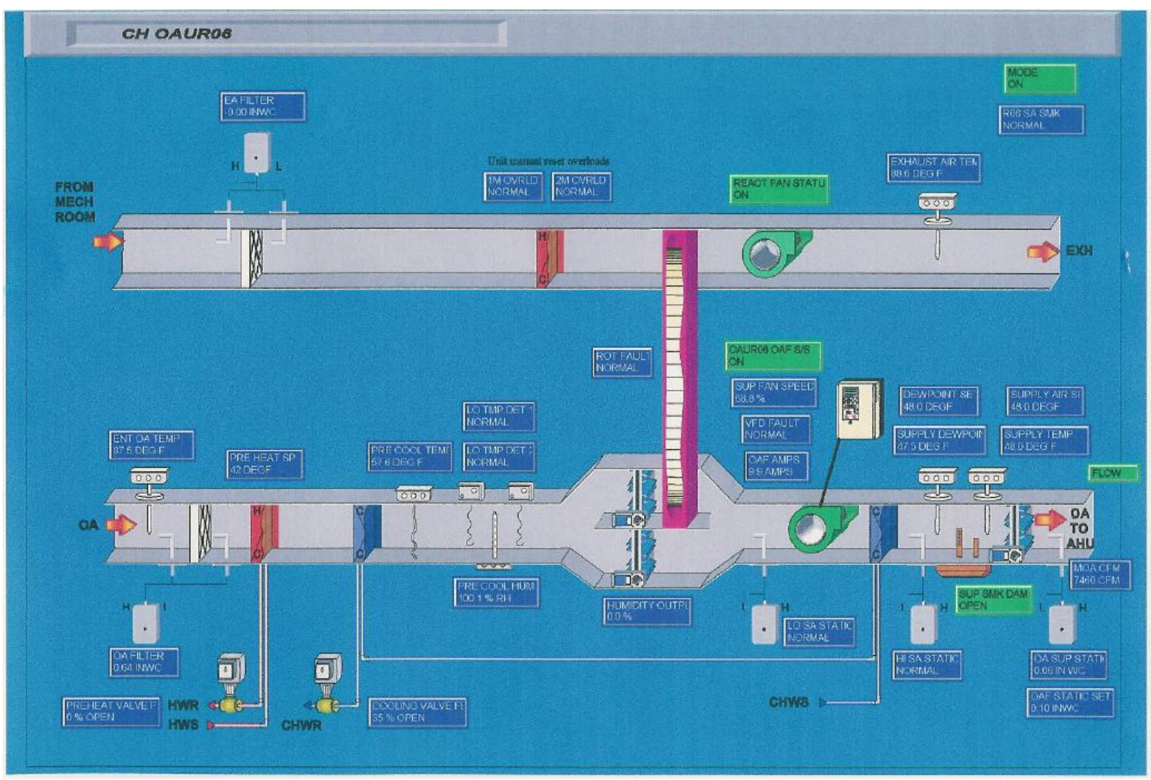

FIGURE 3 SURGERY DEDICATED OUTSIDE AIR HANDLING UNIT SCHEMATIC

The lighting for the hospital was designed with over 10,000 T5 and T8 light fixtures providing an average of approximately 1 watt per square foot. Roughly 33% of these fixtures are connected to occupancy sensors. Critical and patient care areas were not equipped with occupancy sensors. Daylight harvesting controls were provided for corridors, open areas and offices next to perimeter glass, or around 3% of the total fixture count.

Over 90% of the perimeter rooms in the hospital are provided with windows for daylighting and 35% of the diagnostic and treatment areas in the hospital are within 15 feet of a window. The double pane low-E exterior glass was selected to maximize daylight transmittance and minimize solar heat gain with a 0.30 solar heat gain coefficient.

The building automation system (BAS) included the following energy conservation control strategies:

- CO2 demand control ventilation in the administration and public areas,
- unoccupied setback of operating rooms,
- scheduling / night setback for specific areas of the hospital
- economizer cycles on the administration units

Other energy conservation measures that were implemented into the design included:

- underfloor air distribution for 40,000 square feet of administration area,
- right sized distributed air handling units,
- low velocity / low pressure drop sized ductwork and piping,
- low pressure drop ionization filtration on patient care air handling units.

The estimated energy savings of the proposed measures at the end of Design Development was approximately 14%. Final preconstruction energy modeling for the hospital was estimated at 17% better performance than an ASHRAE 90.1 compliant design.

ENERGY PERFORMANCE FROM JULY 2007 THROUGH JULY 2009

The hospital opened on July 1, 2007, approximately two months ahead of the construction schedule. Chilled water consumption for the first three months of operation was 75% over design estimates as shown by Figure 4. Steam consumption followed a similar trend. The original construction schedule incorporated two full months prior to opening date for final commissioning. By July 1st, the majority of the functional testing of the air handling units had yet to be conducted.

The commissioning process was completed by September 2007. Significant progress was made during final commissioning to reduce energy consumption; however, the performance was still far from expectations. A concerted effort was made to determine what could be done to improve energy performance. All rooms and areas were reevaluated for air change rates and minimum VAV flow setpoints. A considerable number of minimum setpoints were modified to take better advantage of the variable air volume capabilities of the air handling units while still maintaining Texas hospital code and ASHRAE 62 required air change rates. Approximately 10% of the total minimum volume was trimmed which equates to roughly 140 tons of chilled water demand.

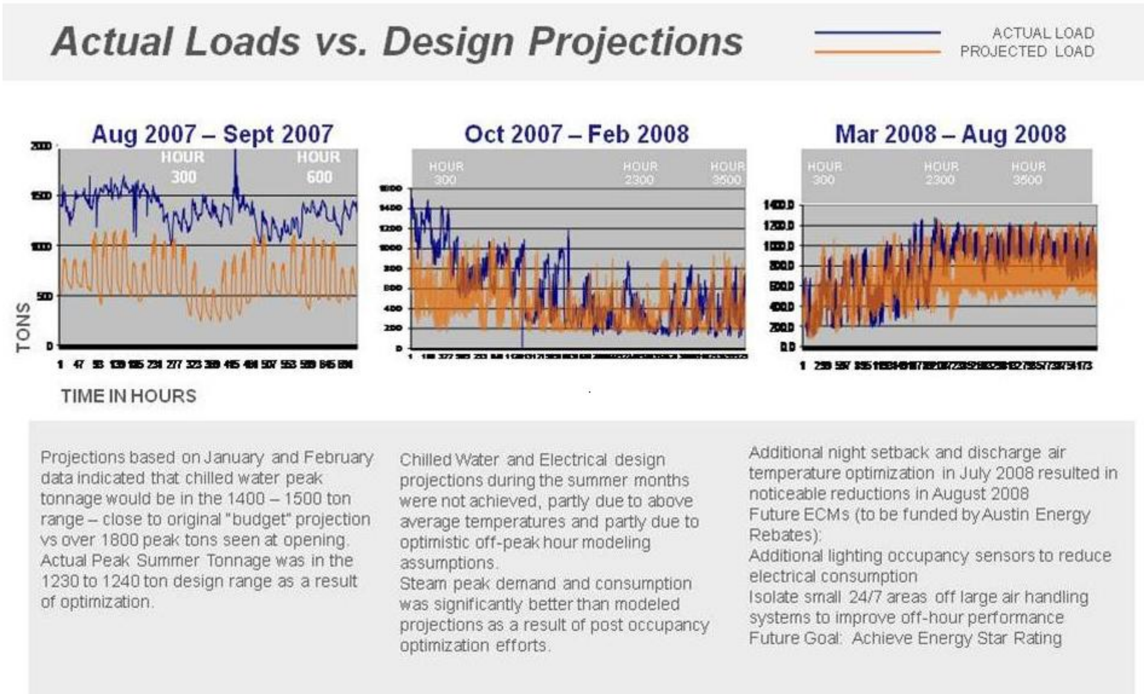

FIGURE 4 ACTUAL COOLING LOADS COMPARED TO DESIGN PROJECTIONS

Cold deck temperature reset based on outdoor air temperature was also implemented into the building automation system during October and November. The specified design leaving air temperatures for the air handling units were in the 48.5F to 49.5F range. With the exception of the surgery air handling unit, cold deck leaving air setpoints were raised to 56F to 59F at outside air temperatures 85F and higher, with the OAU cooling coil leaving air temperatures set at 56F. Although this strategy requires higher air volumes and more fan horsepower than the lower temperatures, the chilled water demand is minimized resulting in significant cost and thermal energy savings. An example of the cold deck setpoints are shown by Table 2.

AHU	Area Served	SAT DEG F	CDS DEGF	CDT DEGF	Fan Heat DEGF	Hot CDS OAT = 85F	Cold CDS OAT = 45F
AHU 1-1	Kitchen/Dining	61	56.2	56.5	4.5	56	61
AHU 1-2	Maint/CSPD	58.7	57.3	57.2	1.5	57	63
AHU 2-1	Surgical Svcs	54.9	53	53	1.9	53	57
AHU 2-2	PACU/PANDA	61.3	57.3	57.4	3.9	57	62
AHU 2-3	IMCU	62.1	59.3	59.1	3	59	63
AHU 2-4	PICU	62.4	59.3	59	3.4	59	63
AHU 2-5	Imaging Svcs	59	56.3	56.4	2.6	56	60
AHU 2-6	Rehab/Spec Care	59.6	58.1	58.1	1.5	58	60
AHU 3-1	Emg. Svcs	60.5	57.1	57.3	3.2	57	59
AHU 3-2	Admitting/Admin	60.3	59	58.9	1.4	59	65
AHU 3-3	Nursing Unit	60.2	59.2	59.3	0.9	59	63
AHU 3-4	Nursing Unit	60.8	59.2	59.4	1.4	59	63
AHU 3-5	Auditorium	62.6	60.8	60.9	1.7	**	**
AHU 3-6	Admin	61.8	61.2	61.4	0.4	61	65
AHU 4-1	NICU/Cardio	61.1	57.2	57.3	3.8	57	62
AHU 4-2	Lab	58.2	56.4	56.5	1.7	56	62
AHU 4-3	Surgical Nursing Unit	61.7	59.2	59.2	2.5	59	63
AHU 4-4	Oncology Nursing Unit	59.9	59.2	59	0.9	59	63
AHU 4-5	Lab	61.3	58.2	58.2	3.1	58	62
Entry	Main Entry	59.9	59.4	59.8	0.1	59	66

Gray Shading Patient Room AHUs
** CDS Reset based on RA

TABLE 2 EXAMPLE – SNAPSHOT OF AIR HANDLING UNIT COLD DECK SETPOINTS

The last major control modification was made with the outside air control. Most areas in the hospital were designed with small shelled areas and rooms for future buildout. The outside air quantity specified for each air handling unit included future requirements. An evaluation was performed to determine minimum outside air requirements for the actual balanced air volumes for each AHU and the percentage of outside air to be maintained for Texas hospital code and ASHRAE 62 air change rates. Continuous outside air tracking and setpoint adjustment were implemented to optimize the outside air supplied to the various areas of the hospital based on the required percentage of OA to SA. This control strategy also enabled the minimum outside air setpoint to be automatically adjusted for patient care areas such as Imaging and Rehab that could be placed into night and weekend setback. The occupied setpoint is restored by any thermostat override in the area. As the areas are built out and the air volume increases, the minimum OA setpoint will automatically be increased to the original design values. An estimated 25,000 cfm of outside air was conserved by this effort, or approximately 15% of the total outside air originally scheduled. In no case is the minimum outside air ever allowed to decrease lower than what is required by code and /or to maintain positive space pressurization.

Design modifications were also made with the control of the Surgery suite desiccant dehumidification outside air unit. This OAU was designed to operate whenever the OA dewpoint was above setpoint and to lower the dewpoint to 28.5F. A control modification was made to use the dessicant dehumidification only when the chilled water coil cannot lower the dewpoint to 48 F. Although no estimates have been made to determine steam energy savings, overall steam consumption for the hospital is significantly less than design projections.

Finally, a substantial effort was made to get approval from the Network IS department to raise Communications closets temperature setpoints were from 68F to 75F . The VAV boxes for these rooms and electrical rooms were not provided with reheat coils, so the VAV box damper is simply allowed to modulate to a position to maintain room setpoint.

As a result of the various control strategies and setpoint adjustments that were implemented, continuous progress has been made over the past eighteen months to improve energy performance as shown by Figure 5, which shows the chilled water consumption history for the hospital on a year over year comparison basis with the design modeling values included. The modeling values are in gold. The first year of operation is shown in maroon, and the second year of actual ton-hours is shown in blue.

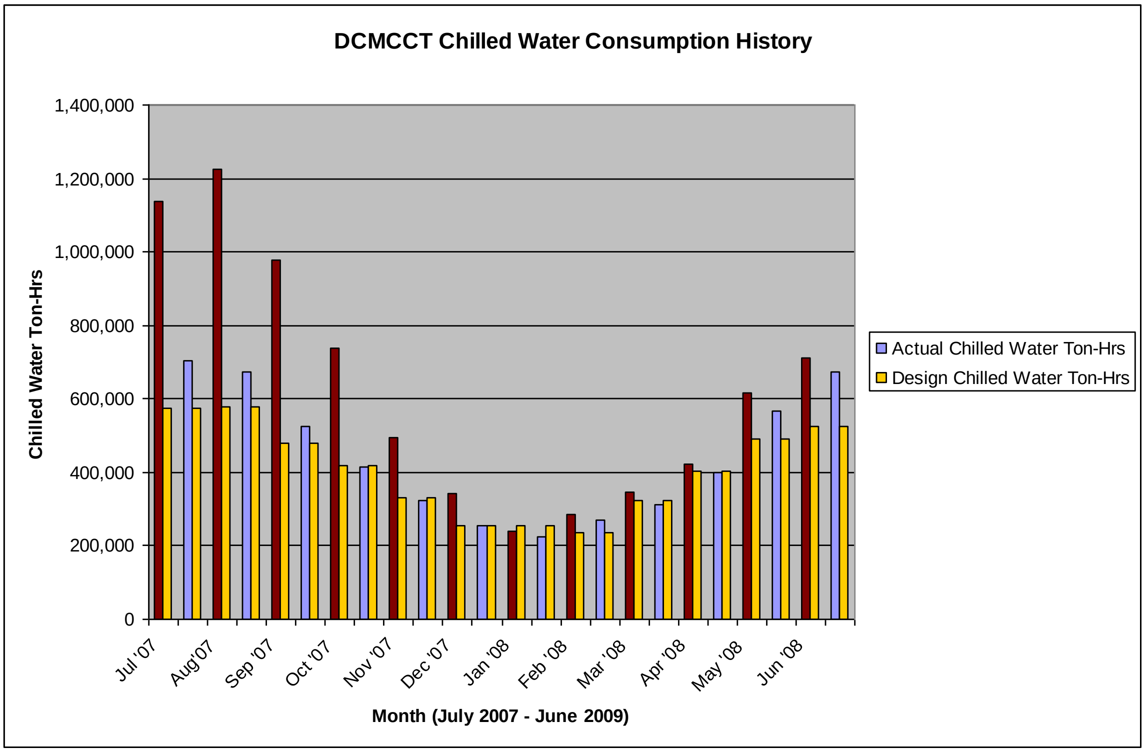

FIGURE 5 CHILLED WATER CONSUMPTION HISTORY

Figure 6 shows the actual peak tons versus design projections for the first two years of operation. The blips in peak tonnage in December 2008 and April 2009 were caused by “user error”. Several of the discharge air temperatures were overridden by Plant Operators due to staff complaints about the spaces getting too warm during off hours. Further adjustments were made and no problems have occurred since April.

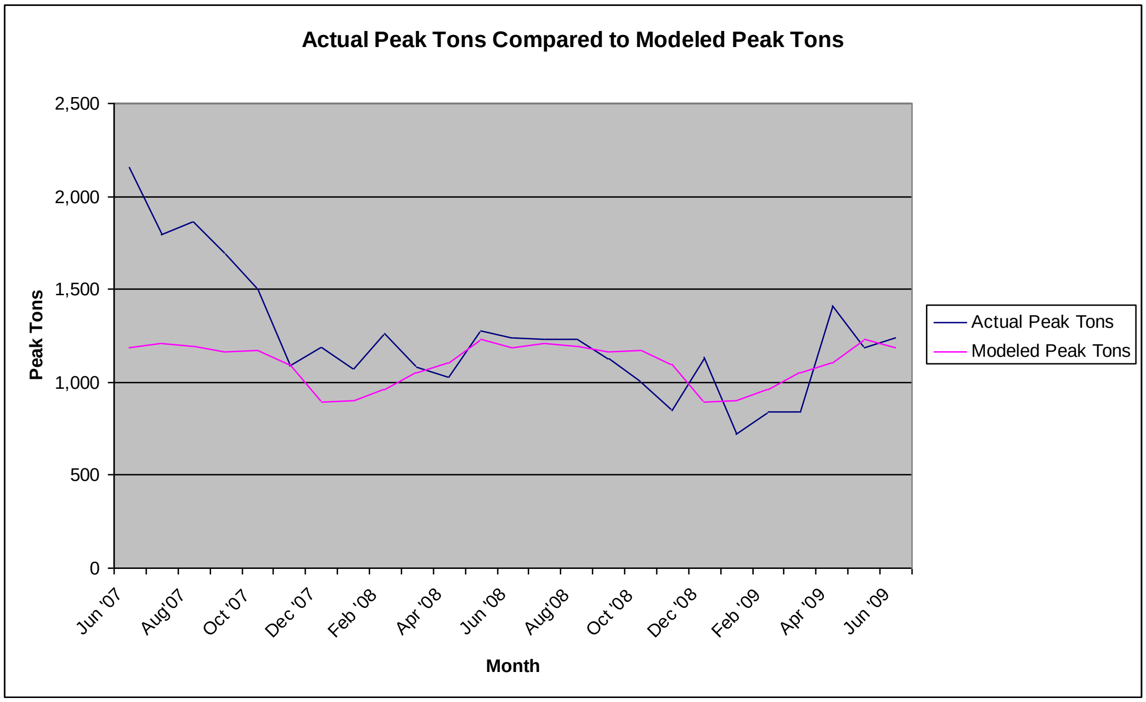

FIGURE 6 ACTUAL PEAK CHW LOADS COMPARED TO DESIGN PEAK LOADS

Figure 7 shows the actual hourly chilled water ton-hours versus design projections for June and July 2008 and 2009. The 2008 data is shown in yellow and 2009 is in blue. The energy model projected loads is shown in pink. The actual peak loads in both years are very close to projections with a few exceptions when the load exceeded 1200 tons in 2009.

The higher loads in 2009 can be partially explained by the failure of all of the evaporative spray pumps on the five Outside Air Units. The estimated load reduction by all the spray units is approximately 150 tons on a peak load day. Throughout the month of July it is estimated that the total chilled water consumption would have been 50,000 ton-hours less if these units had not failed. Another contributing factor was that a new 10,000 cfm air handling unit was brought on line at reduced capacity in June 2009 to serve a 6,500 square foot OR addition.

It should also be noted that the actual minimum loads are well above the projected minimum loads throughout the summers of both years. Part of the explanation for this discrepancy is that many of the air handling units that were modeled to be set back or turned off during nights and weekends cannot be operated in this manner due to one or two areas or rooms in the air handling unit distribution zone that must be kept cool 24/7 due to the functions of the rooms.

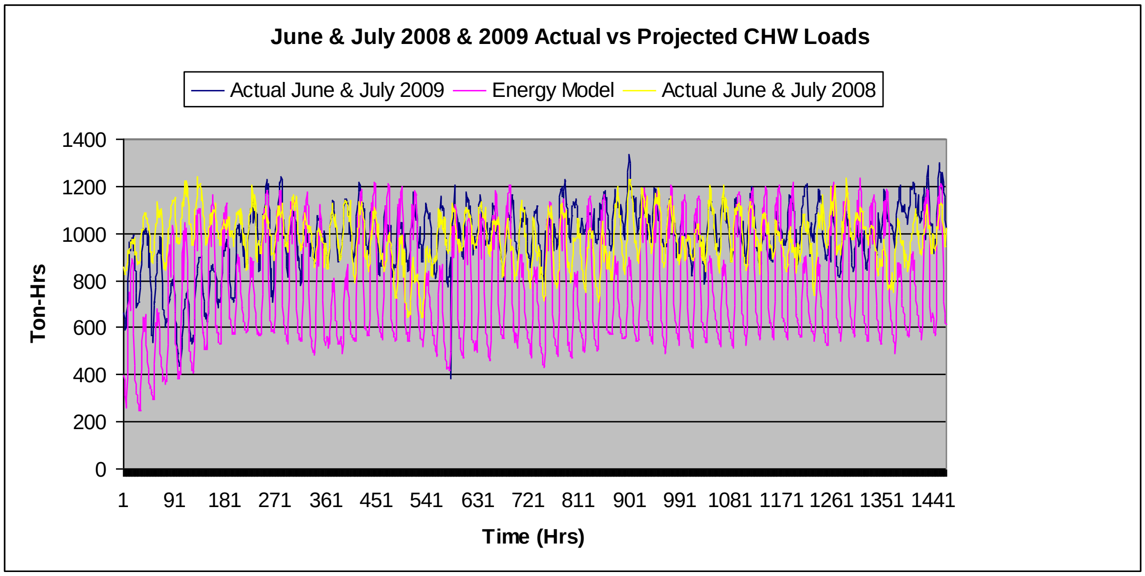

FIGURE 7 ACTUAL HOURLY CHW LOADS COMPARED TO DESIGN LOADS

The most obvious reason for the significant variances between actual and projected peak, minimum and monthly loads during the 2008 and 2009 summer months is above average hot weather. The ASHRAE 1% occurrence design temperature for Austin is 97.5F with a mean coincident wet bulb of 74.5F. The average number of cooling degree days for the months of June, July and August are 494, 605 and 610 respectively.

Figure 8 depicts the cooling degree day history for the time period from July 2007 through July 2009. Figures 9 and 10 are excerpts from the Austin, Texas American Statesman daily newspaper, and the following highlights from the National Weather Service indicate the extreme summer weather conditions experienced during 2008 and 2009:

- June 2008 was the warmest June on record with an average monthly temperature was 87.4 degrees F. The average monthly temperature for June is 81.5 F.
- The average monthly temperature of 86.6 in June 2009 made it the 2nd warmest on record. In addition, June 2008 holds the record for the number of 100 plus degrees days at 20.
- June 2009 had 16 days of 100 degrees or higher temperatures and the most consecutive days of 100 degrees or higher at 10 days up from 8 in June of 1925.
- The period between June 22 and July 21, 2009 was the warmest 30-day period on record with an average temperature of 89.7F.
- July 2009 was the warmest month and warmest July on record with the average temperature of 89.5 F exceeding the old record of 89.1 set in July of 1860. The average monthly temperature for July is 84.5 F.
- The average maximum of 99.1 in July of 2008 tied for the 6th warmest average high.
- July 2009 set a new all-time highest monthly average minimum temperature of 76.9 breaking the old record of 76.7 set in 1998.
- July 2009 also set a new record for the highest average maximum temperature of 102.0F breaking the old record of 101.7 set in 1923.
- Twenty-six 100 plus degree days were observed at Austin Mabry during July of 2009, one day less than the record of 27 observed in July of 1925.

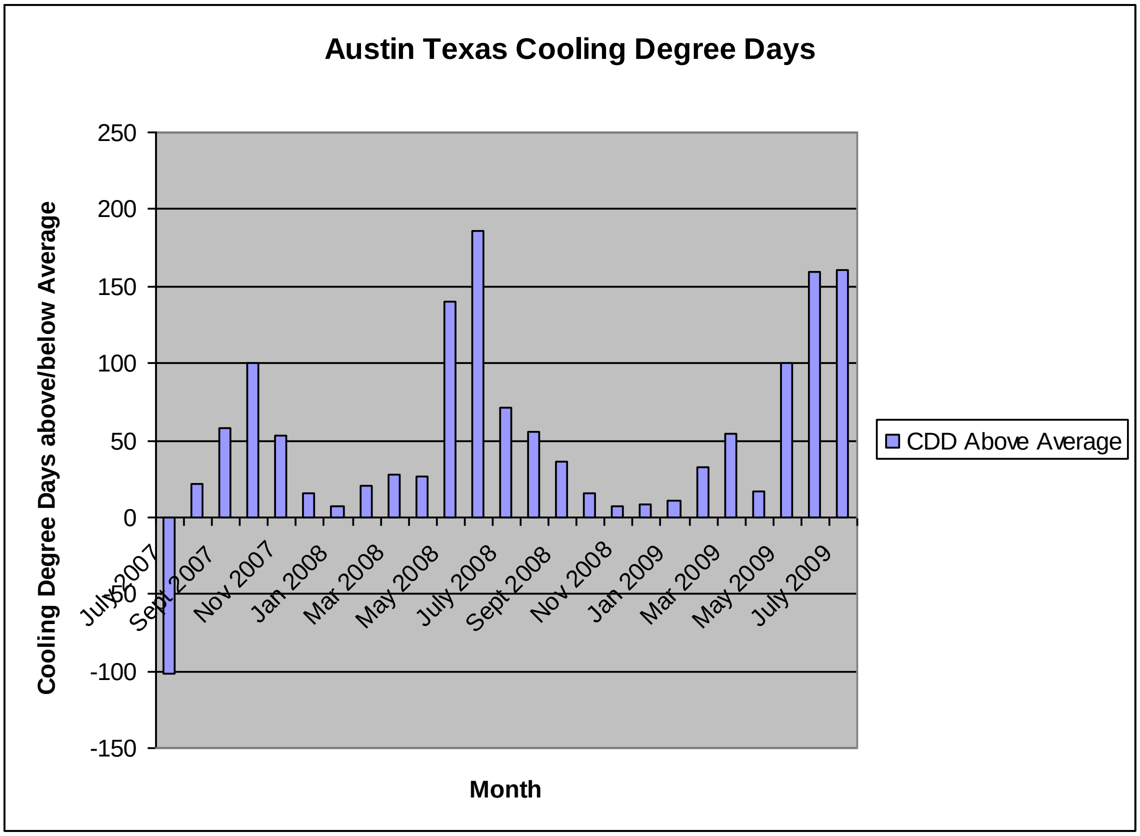

FIGURE 8 ACTUAL COOLING DEGREE DAYS VARIANCE ABOVE AVERAGE FROM JULY 2007 THROUGH JULY 2009

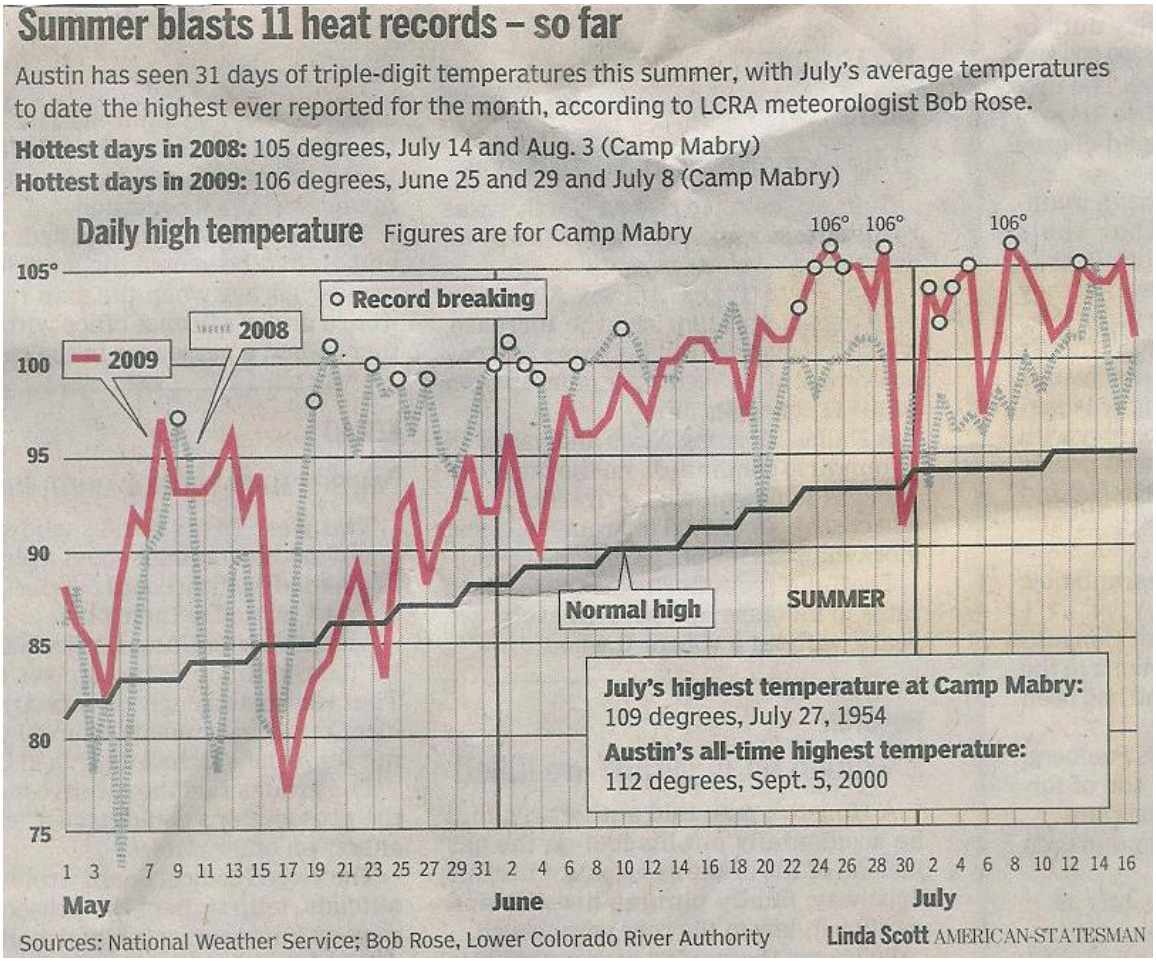

FIGURE 9 AUSTIN TEXAS DAILY HIGH TEMPERATURES DURING MAY, JUNE AND JULY 2008 & 2009

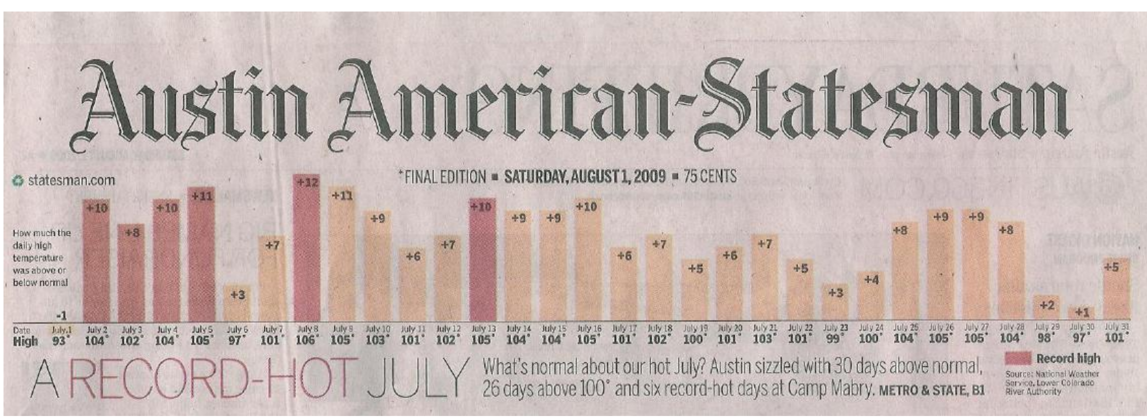

FIGURE 10 AUSTIN TEXAS DAILY HIGH TEMPERATURES JULY 2009

Table 3 summarizes the hospital's energy consumption variance above design projections on a monthly basis beginning January 2008 and the associated monthly cooling degree days variance above average. Even with the extreme summer heat during 2008 and 2009, the energy performance for the hospital was within 5% of the modeling projections. During this same period there have been approximately 25% more cooling degree days than the average weather data used for the modeling.

The correlation between the chilled water consumption and cooling degree days is easily made since the consumption tracks nicely during the winter and cooler times of the year.

It is interesting to note that the lower than projected steam consumption more than offsets the above average chilled water consumption during the warmer periods of the year. Without being able to adjust the original energy model to account for the control system modifications that were made post-commissioning, it is reasonable to assume that most of the steam consumption reduction is directly attributable to less reheat being required as a result of the discharge air temperature reset provisions that were implemented.

Electrical consumption is typically from 3% to 13% above design projections. It is reasonable to extrapolate that most, if not all, of this discrepancy is a result of additional fan horsepower required to move more air due to raising the air handling unit discharge air temperatures in order to lower chilled water consumption. This penalty in electrical consumption is much less than the chilled water and steam savings gained. Another factor that is contributing to the higher than expected electrical consumption is numerous issues with the daylight harvesting system that has prevented proper operation of the system since the hospital opened.

Month	CDD % of Average	TH % of Design	Stm % of Design	KWH % of Design	Total MMBTU % of Design
Jan '08	200%	94%	118%	111%	108%
Jan '09	257%	88%	102%	112%	100%
Feb '08	205%	120%	110%	114%	115%
Feb '09	283%	114%	97%	112%	107%
Mar '08	147%	107%	111%	103%	107%
Mar '09	192%	97%	88%	106%	97%
Apr '08	118%	105%	102%	106%	105%
Apr '09	112%	99%	93%	104%	99%
May '08	143%	126%	79%	109%	111%
May '09	131%	116%	68%	113%	104%
Jun '08	138%	136%	67%	106%	113%
Jun '09	132%	129%	61%	113%	109%
Jul '08	112%	122%	65%	110%	106%
Jul '09	127%	134%	62%	110%	112%
Aug'08	109%	116%	55%	112%	101%
Aug'09	TBD	TBD	TBD	TBD	TBD
Sep '08	108%	110%	64%	110%	99%
Sep '09	TBD	TBD	TBD	TBD	TBD
Oct '08	108%	99%	82%	98%	94%
Oct '09	TBD	TBD	TBD	TBD	TBD
Nov '08	114%	98%	103%	121%	106%
Dec '08	162%	100%	118%	118%	112%
Average	125%	114%	87%	110%	105%

TABLE 3 SUMMARY OF MONTHLY ENERGY CONSUMPTION

CONSTRUCTION AND WARRANTY PHASE ISSUES

Commissioning for the project extended for several months past the date that the hospital opened due to an accelerated construction schedule mandated by the Owner. Many issues were discovered and resolved during this post construction period, the more notable of which are summarized below.

1. Electrically Enhanced Ionization Air filters: The electrical harness cables of the combination media-electronic filters failed due to high humidity during the construction phase of the project. The manufacturer replaced all the cabling once during construction and again soon after the hospital opened. Since the last replacement the filters have been working properly with the exception of several control modules. Concern has developed over the past few months over a black, gritty deposit on the metal surfaces of the filter units.

2. OAU Steam Preheat Coils: Improperly sized steam preheat coils were discovered during the commissioning period during functional testing. All coils were replaced by the manufacturer prior to final acceptance of the units.

3. OAU Humidifiers: BAS control and condensate drain issues with the OAU humidifiers were resolved during the warranty period. Shutdown of the OAUs was a common occurrence during cold, dry weather due to steam not being completely absorbed by the airstream and the duct smoke detectors shutting down the OAU.

4. OAU Heat Pipe Spray Assemblies: New drain pans were added and drain piping modifications had to be made before the spray units could be placed in operation near the end of the warranty period. After the warranty period expired, three of the five spray pumps have failed.

5. Surgery Unit Fail-over Sequencing: An issue with the restart after shutdown control sequence was identified during commissioning, but could not be fixed and thoroughly tested prior to opening the hospital. After a number of short duration scheduled shutdowns of the surgery area, the control logic was modified and the issue was resolved during the warranty period.

6. Surgery Unit HEPA Filters: It was discovered through post-commissioning efforts after the hospital was in operation that the HEPA filters were not meeting particulate efficiency standards. The filters were replaced and the IAQ issues were resolved during the warranty period. There is still an issue with the HEPA filter frames and filter hold down mechanisms. It is probable that the original filters were damaged during installation due to the difficulties of securing the filters in the frame and ensuring that the gasketing on the front edge of the filters was seated properly. As of the date of this report, discussions are ongoing with the air handling unit manufacturer for an acceptable resolution to the issue.

7. Administration Air Handling Units - The two administration AHUs, associated VFDs and distribution systems were commissioned without any issues with the exception of the underfloor air distribution system and proper operation of the economizer cycles. Issues with the UFAD OEM transformers, wiring and controls were resolved prior to final acceptance of the systems.

8. BAS Issues
   - The functional performance and efficiency of the BAS were suspect during commissioning due to problems with the primary communications link being over the hospital IS network. Dramatic improvements have been made during the warranty period; including resolution of Data Loss events. However, random periods of sluggishness still exist.

   - Problems with air handling unit airflow monitor station transmitter calibration and VAV box airflow calibration factors persisted throughout the commissioning period and into the warranty period. A “drift” issue was discovered early during the commissioning period with the airflow monitor transmitters. All transmitters were replaced with ones of a different manufacturer prior to final commissioning. No problems with transmitter drifting have occurred since replacement. After the drift issues were resolved, the flow measurements of the air handling unit airflow monitoring stations were not within 10% or less of the summation of the AHU VAV box airflow values for almost one-half of the 21 air handling units. Final resolution of this problem, which was primarily caused by erroneous VAV box calibration factors, was not achieved until well into the warranty period.

- Issues with the specification and selection of several domestic water flow meters and the low and medium pressure steam flow meters were never addressed due to cost issues. The domestic water flow meters scaled up due to calcium buildup on the paddlewheels. The low and medium pressure steam flow meters were selected for peak flows and do not provide reliable readings at normal and low flows.

- Issues with the economizer cycle control sequence for the two administration air handling units were discovered during commissioning, but not resolved until well into the warranty period.

- Several differential pressure transmitters across filters and heat pipes at the outside air handling units were improperly selected and not changed out until during the warranty period.

9. Daylight Harvesting System: The functional performance of the daylight harvesting system did not meet specifications and resolution of this issue is still ongoing past the warranty period. Over ½ of the approximately eighty controllers throughout the hospital failed during the warranty period and are still in the process of being replaced due to several delays in obtaining replacement parts. A related issue was that the specifications did not require components and associated software to easily troubleshoot and adjust the controllers.

10. Issues with the placement and control settings of occupancy sensors not being in accordance with the specifications and manufacturer’s instructions were discovered after the hospital opened due to numerous staff complaints. These issues were resolved during the warranty period.

11. The heating water heat exchanger equipment and control valves were commissioned without any issues except that the 1/3-2/3 steam control valves on one of the heat exchangers were programmed such that the larger control valve functioned as the smaller control valve. This problem was discovered through post commissioning trending and promptly resolved.

12. Communication room AC unit control issues with fan on-off control were addressed and resolved during commissioning. The problem was that the CRAC unit fans came from the factory to run continuously when the units were not required for cooling. Additional BAS programming was required to turn the fans off whenever the thermostat was satisfied. Another programming issue surfaced during commissioning of the two main server Data Room CRAC units. The failover sequence was locking the backup unit out of service after a power glitch or failure. This problem was resolved during the warranty period

13. During functional performance testing it was discovered that a new exhaust fan needed to be purchased and installed for

the Pharmacy Chemo IV Prep clean hood. The original exhaust fan was designed for a hood without a HEPA filter on the exhaust side. The hood was purchased with a HEPA filter and the pressure drop was much higher than designed. The new fan was commissioned and performance tested prior to final acceptance.

14. The exhaust ductwork at OAU R-5 caved in due to the fan not shutting down when a smoke damper on the main duct closed. The control issue with the fan shutdown was resolved during commissioning. However, repair of the exhaust duct was never resolved since the ductwork met the material and installation specifications.

15. Domestic Hot Water System: A problem with an undetermined hot-cold water cross connection was discovered after the hospital opened from hardness testing of the water by the Owner. The problem persisted for several months until the domestic hot water return piping was routed back through the water softeners. The cross connection was never found. This issue caused scaling and capacity issues with the clean steam humidifier heat exchangers fed by soft water. Another issue with the recirculation pumps being undersized is in the process of being addressed.

16. A RO/DI water system serving the clean steam generator for the sterilization autoclaves and washer had to be redesigned and replaced after occupancy due to capacity issues.

LESSONS LEARNED

Lessons learned during the design and construction phases of the project from the Owner's perspective are summarized below:

Design Phase

- Join the building design engineer and energy modeler at the hip during schematic design and don't let them separate until after construction documents have been completed.
- An accurate 24/7 energy profile is needed for the CHP design. It is recommend that a minimum of 4 iterations (SD, DD, CD prelim and CD final) be performed.
- The HVAC/control system design must comprehensively implement the energy conservation strategies used for the energy modeling.

Commissioning-Construction Phase

- Thorough submittal review is required to ensure ECMs are met per design intent and that even obvious things do not fall through the cracks.
- The construction manager / general contractor should build the construction schedule with priority given to complete all commissioning prior to occupancy.
- Conduct post-commissioning after occupancy for greater energy savings.
- Evaluate and adjust design setpoints and parameters after occupancy to optimize energy performance.
- Energy Management requires operations staff training beyond O&M training.
- Owner commissioning offers several advantages, the most beneficial of which is the ability to stay with the project through the warranty period to help identify and ensure that problems are addressed.

MISSED ENERGY CONSERVATION OPPORTUNITIES

In hindsight, there were a number of design measures that were not considered or thoroughly thought through during the schematic and design development phases of the project that would have improved the hospital's energy performance, as listed below:

- Economizers for all air handling units
- Smart lighting controls
- Individual fan coil units for 24/7 areas such as on-call rooms, security offices, etc
- UV in air handling units in lieu of ionization filters
- Better monitoring sensors and in more locations (air and water flows and lighting)
- Lab exhaust heat recovery and VAV fume hoods

FUTURE IMPROVEMENTS

Several opportunities have been identified throughout the hospital for additional energy savings that were not part of the base building design. Estimated payback periods for the measures are between one and three years. These measures primarily consist of additional lighting controls, minor HVAC system changes and BAS control modifications, as follows:

- Parking garage occupancy sensors
- Exterior stairwell lights photocells and occupancy sensors
- Additional occupancy sensors for mechanical, electrical and other miscellaneous rooms throughout the hospital
- Fan coil units for Security, and Surgery / Anesthesia On-call rooms
- BAS Static Pressure Reset
- Modifications and repair to existing Daylight Harvesting system